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METHOD OF TESTING OXYGEN REGULATORS

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National Bureau of Standards

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SUMMARY

A method of calibrating aircraft oxygen regulators has been devised in which the instruments in one chamber are maintained at a constant air pressure corresponding to any desired altitude while the volume flow of the delivered oxygen is measured in another chamber at the same pressure. It has the chief advantage over methods hitherto used in that a condition of steady flow of the oxygen through the apparatus is obtained before the rate of flow is measured. The method is also very useful in disclosing any leaks which may occur in the regulators at the higher altitudes only and thus are not detectable at ordinary atmospheric pressures. The apparatus is described and an example of the computation of the actual rate of flow is given.

The work was carried out at the National Bureau of Standards, in part with the cooperation and financial assistance of the National Advisory Committee for Aeronautics.

INTRODUCTION

Oxygen regulators are used in aircraft to regulate automatically the flow of oxygen to the pilot from a cylinder at pressures ranging up to 150 atmospheres. The instruments are adjusted to open at an altitude of about 15,000 feet and thereafter to deliver oxygen at a rate which increases with the altitude. The instruments are tested to determine the rate of flow of oxygen delivered at various altitudes and to detect any mechanical defects which may exist. A method of testing oxygen regulators was desired in which the rate of flow could be determined more accurately than by the test method previously used (reference 1) and by which instruments defective mechanically could be detected. The new method of test fulfills these requirements.

## DESCRIPTION OF THE APPARATUS

The apparatus includes an airtight chamber such as a bell jar and base B (fig. 1), a gas meter G, a tank T of large capacity, and a vacuum pump P. In addition there is a U-tube water manometer M, and a mercurial barometer A. Several valves connected as shown in the figure are required for regulating the pressure within the apparatus.

The oxygen gas issues from the regulator under test and passes through rubber tubing of large internal diameter to the vertical manifold in the bell jar. From there it flows through tubing of one-half inch bore to the inlet side of the meter. From the outlet of the meter it flows into the tank through the line which includes valve  $V_2$ . (See fig. 1.)

A bellows-type gas meter (fig. 2) mounted in an iron case which is capable of operating under line pressures ranging from atmospheric pressure to about 25 inches of mercury below atmospheric pressure is used. Its indicating mechanism is equipped with a tangent arm making nine revolutions per cubic foot of gas flowing through the meter. A pressure across the meter amounting to about one half inch of water is required for operation.

In order that the meter be absolutely airtight all openings are sealed and a heavy glass window is installed directly over the tangent arm so that its movement can be observed. An index marked on the window is an aid in counting the whole and fractional part of the revolutions through which the tangent arm turns during a test.

The mercurial barometer measures the absolute pressure, or equivalent altitude, in the bell jar.

The temperature of the oxygen is measured by a mercury-in-glass thermometer placed in the entrance chamber of the meter.

Rubber tubing is used for the bypass across the two ends of the water monometer. Valve  $V_3$  is a quick-releasing clamp which pinches the walls of the tubing together. Valve  $V_4$  is also a clamping valve, not quick-releasing as it is used to regulate the oxygen flow.

Valves  $V_5$  and  $V_6$  are metallic needle valves with the seat part of the valve connected to the bell jar. With this arrangement the stuffing boxes may leak and not affect the pressure in the bell jar.

Valves  $V_2$  are small, high-pressure, needle valves connected to a manifold so that the stuffing boxes are subjected to the high-pressure oxygen only when the valves are open. Each of these valves controls the flow of oxygen to one regulator when provision is made for mounting more than one regulator on the base of the bell jar. An extra valve is used to exhaust the gas from the manifold when desired. A filter is placed in the line between the manifold and the oxygen cylinder to clean the oxygen.

Each regulator is individually vibrated during tests by means of an electric buzzer.

#### OPERATION OF THE APPARATUS

Initially valves  $V_1$ ,  $V_2$ ,  $V_4$ , and  $V_5$  are closed and valves  $V_3$  and  $V_6$  are open. The pressure of the whole system including the bell jar, meter, and tank is reduced to that corresponding to the altitude at which the test is to be made. Valve  $V_6$  is then closed and the pressure in the tank is reduced to at least 30 mm of mercury less than the pressure in the bell jar and meter. While oxygen is flowing during a test, the tank is being evacuated continuously by means of the vacuum pump.

With approximately the correct pressure in the bell jar, valve  $V_3$  is closed and the desired pressure, or equivalent altitude, in the bell jar is obtained by adjustment of valves  $V_5$  and  $V_6$ .

Valve  $V_4$  is opened slightly until the manometer shows that the meter is at a pressure slightly less than that in the bell jar. This is done so that the rapid increase in pressure obtained when the oxygen is turned on will not blow the water out of the manometer before pressure adjustments can be made.

Valve  $V_1$  is opened and the electric vibrator mounted on the instrument to be tested is started.

Valve  $V_2$  leading to the regulator to be tested is then opened in order to start the flow of oxygen. At the same time valve  $V_4$  is opened and adjusted so that the absolute pressure in the meter is the same as that in the bell jar, as indicated by the water manometer. Valve  $V_4$  must be continuously adjusted during the test to keep this pressure equal. After the gas is flowing steadily the time for a given number of revolutions of the tangent arm of the meter is obtained with a stop watch.

When testing more than one instrument it is necessary to close valve  $V_2$  leading to the first instrument tested and after the flow of oxygen has stopped to open the valve leading to the second instrument.

The change to any other desired pressure in the bell jar and system is made by adjusting valves  $V_5$  and  $V_6$  with valves  $V_1$  and  $V_2$  closed and with valve  $V_3$  open.

The accurate determination of the rate of flow depends primarily on:

1. Accurate control of the pressure of the oxygen in the meter so that it is equal to the air pressure in the bell jar.
2. Accurate timing of the revolutions of the tangent arm of the meter.
3. Low pressure drop in the line between the oxygen regulator and the meter.
4. Constant pressure in the bell jar during the test.

#### TESTS AT LOW TEMPERATURE

In testing oxygen regulators at low temperature it is necessary that the meter be maintained at room temperature. Only the bell jar, therefore, is installed in the temperature chamber and the lines connecting with the rest of the apparatus are brought out through a hole in the wall of the chamber. A ten-foot length of copper tubing of large internal diameter (one half inch) is used to connect the manifold in the bell jar with the meter. Most of this length is outside of the temperature chamber. The line is broken

about its midpoint and then joined by a short piece of rubber tubing thus reducing the loss of heat from the meter by conduction along the copper tube. It was found with this arrangement of tubing that the temperature of the oxygen leaving the regulator at  $-35^{\circ}\text{C}$ . is increased to approximately that of the room when it enters the meter. In all other respects the testing procedure is the same as that for tests made at room temperature.

#### MEASUREMENT OF RATE OF FLOW

The rate of flow of oxygen  $F$  in terms of liters per minute at a pressure of 760 mm of mercury and temperature of  $+20^{\circ}\text{C}$ . is given by the relation:

$$F = \frac{P}{p_0} \frac{T_0}{T} \frac{V}{t} \quad (1)$$

where  $P$  is air pressure in bell jar in mm of mercury

$p_0$ , standard pressure of 760 mm of mercury

$T_0$ , standard absolute temperature of  $293^{\circ}\text{C}$

$T$ , temperature of oxygen in gas meter in  $^{\circ}\text{C}$

$V$ , observed flow in liters

$t$ , observed time in minutes for flow  $V$

$V = 28.35 \frac{N}{9}$  where  $N$  is the number of revolutions of the tangent arm of the gas meter described above when

$t$  is observed in seconds,

$t/60$  is time in minutes.

With these additional relations and putting into equation (1) the values of the constants, there results:

$$F = \frac{293 \times 28.35 \times 60}{760 \times 9} \frac{p}{T} \frac{N}{t} \quad (2)$$

$$= 72.9 \frac{p}{T} \frac{N}{t} \quad (3)$$

The following example illustrates the method of determining the rate of flow.

An oxygen regulator was installed in the bell jar at an air pressure corresponding to an altitude of 35,000 feet (178.7 mm of mercury). The oxygen supply was turned on and the time interval for five revolutions of the tangent arm of the meter was found to be 16.0 seconds. The temperature of the oxygen as measured in the entrance chamber of the meter was +25°C. (298°C). Substituting the known values in equation (1) above

$$\text{Flow} = 72.9 \frac{178.7 \times 5}{298 \times 16}$$

$$= 13.7 \text{ liters per minute}$$

If it is desired to measure the rate of flow at a few definite altitudes the computations can be simplified by combining the pressure  $P$  with the constant of equation (3). Further, if the time is measured for the same number of revolutions of the tangent arm of the meter the term  $N$  may also be included with the constant. Formula (3) then becomes

$$F = \frac{K_1}{Tt} \quad (4)$$

A table may be prepared giving the values of  $K_1/T$  for the desired altitudes and for different temperatures. The computation required for determining the rate of flow then becomes one of the simple division of the number properly selected from the table, by the elapsed time in seconds.

#### EFFECT OF LEAKS

The testing apparatus should be leak-tight for the best results. A small leak which does not increase the pressure in the bell jar at a rate exceeding about 0.2 mm of mercury per minute has been found by experience with the use of the apparatus not to affect appreciably the accuracy of the method of measurement. It is desirable to compensate for the effect of a leak, however, by opening valve  $V_6$  and adjusting it so that the pressure within the bell jar remains constant. A small leak in that part of the

system lying between the meter and the vacuum pump and including tank T does not affect the results of the tests but does impose a greater load on the pump.

Diaphragm-actuated valves are used in the construction of oxygen regulators to reduce the pressure of oxygen as it issues from the cylinder to a predetermined value which exceeds the atmospheric pressure. Upon failure of a diaphragm, which may occasionally occur, the oxygen is wasted before it is delivered to the pilot. It is important, therefore, that any leaks, which may be present in the regulators, be detected before the instruments are used. An increase in the pressure indicated by barometer A is the direct evidence of a leak in the regulator to which oxygen is being delivered from the supply cylinder.

### CONCLUSIONS

The results of tests made on a large number of oxygen regulators have shown the value of this method of test for accurately determining the rate of flow and for detecting leaks in the instruments. In addition a condition of steady flow of the oxygen through the apparatus can be maintained for any desired length of time. No observations covering a period of less than 15 seconds are made due to the increased inaccuracy of determining the time interval over a shorter period. The method is an improvement over that previously employed in that a precise control of the air pressure to which the regulators are subjected is obtained, and in the facility with which leaks are detected.

### REFERENCE

1. Hunt, F. L.: Oxygen Instruments. T.R. No. 130, N.A.C.A., 1925.

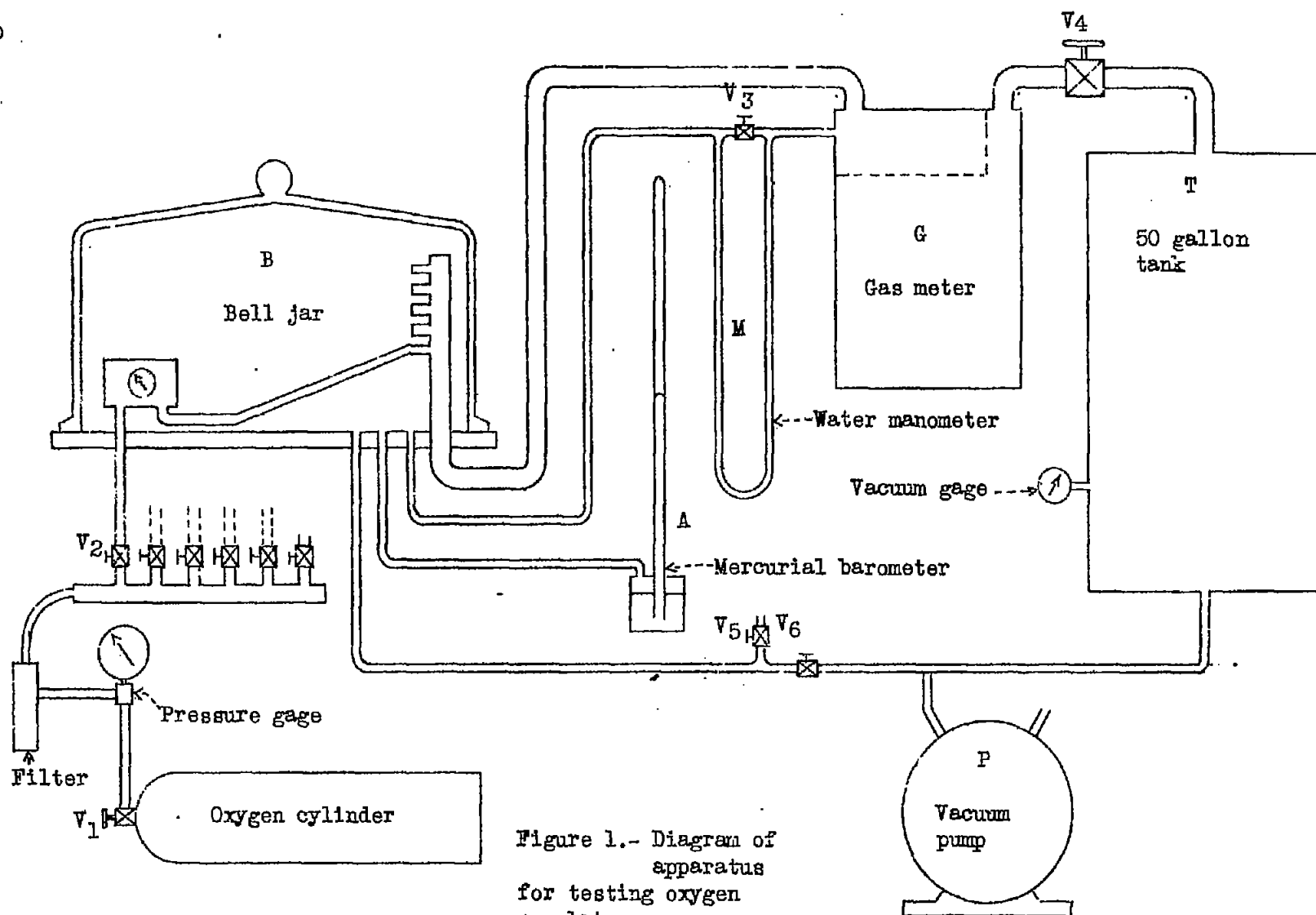


Figure 1.- Diagram of apparatus for testing oxygen regulators.

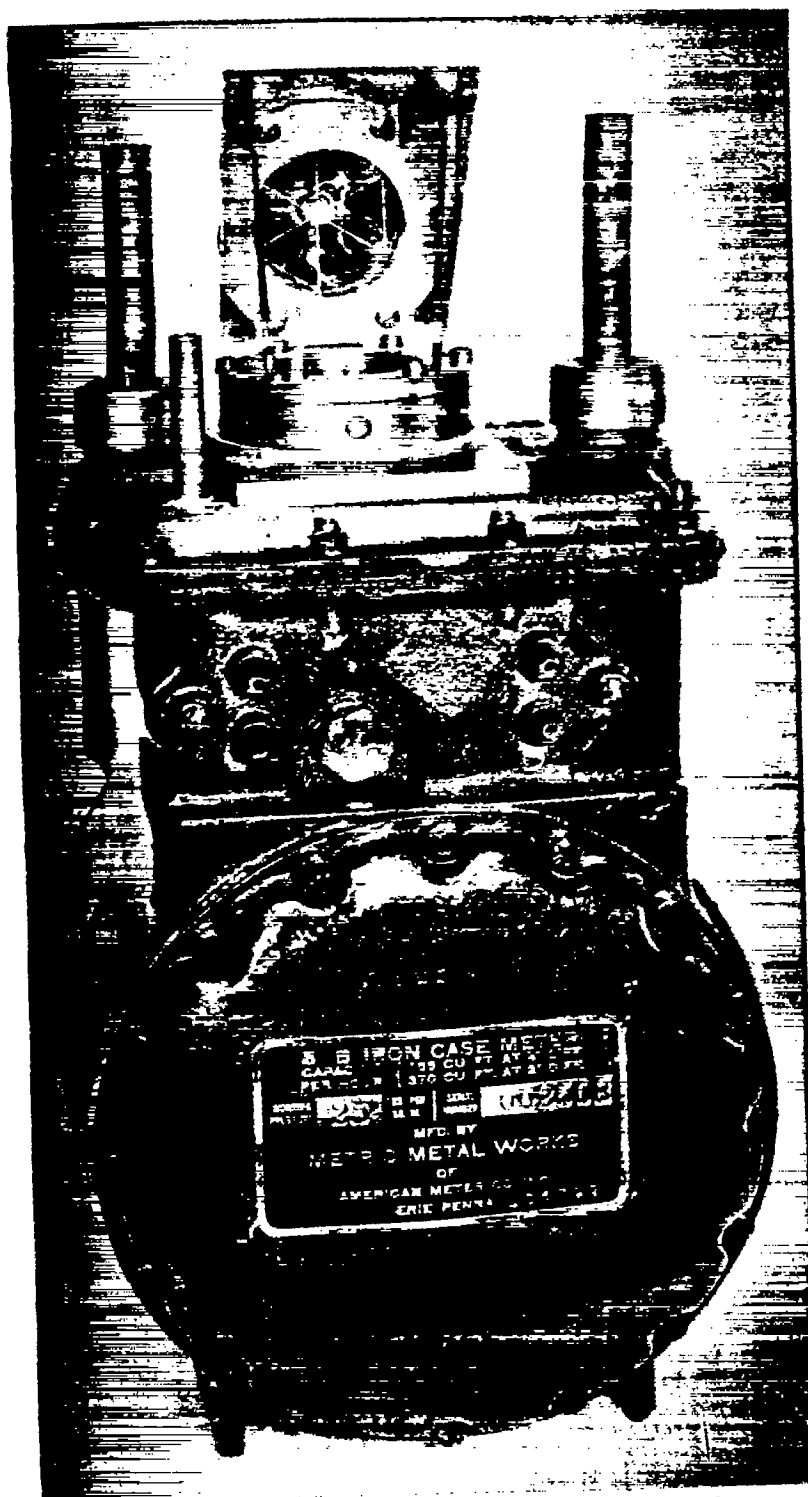


Figure 2.- Photograph of modified gas meter.